DETERMINATION OF ACCESS TIMES TO RAIL RAPID TRANSIT STATIONS WITHIN THE CITY OF CHICAGO

by

Inwon Lee
and
Howard Permut

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Planning and Development Department
Regional Transportation Authority
(Northeastern Illinois)
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Chicago, Illinois 60654

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ABSTRACT

This paper addresses the question of access mode and travel time to rapid transit stations within the City of Chicago. An analysis of an existing disaggregate data set was undertaken to determine: (1) the distance from a rapid station at which people walk, as opposed to ride the bus, to the station; and (2) the travel time in both unfactored and equivalent time (with unequal weightings of trip components) by the bus for people traveling a given distance. An indifference distance of one-half mile was determined, and models which express travel time, in both unfactored and equivalent time, as a function of distance developed.

INTRODUCTION

This analysis was undertaken to determine the functional relationship between distance from a rapid transit station and access time and mode to that station for home-based trips originating within the City of Chicago. Access time is defined as travel time from the origin to the rapid transit station, but does not include entrance time to, or waiting time at the station.

This information is invaluable in the estimation of CBD demand on new rapid transit facilities. It allows simple distance measurements to be converted directly into access times, eliminating the need for a coded feeder bus network.[1]

Disaggregate models based on individual trips are developed for both unfactored and equivalent access travel times.[2] These models are then tested for their accuracy when applied to aggregate square-mile traffic zones. The unfactored time model provides more accurate results than the equivalent time model. Reasons for this are explained. Finally, the applicability of the results are discussed.

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[1] A few express bus routes which compete with rapid transit lines for line-haul CBD trips may still be required for mode-split analysis. However, an overwhelming majority of existing bus routes would not be required (an estimate for Chicago is that only six percent of the routes operated by the CTA would be needed).

[2] Unfactored travel time is the sum of all trip components, while equivalent travel time is defined as the sum of in-vehicle time and twice out-of-vehicle time.

Base Data

This analysis used existing data representing individual peak-period trips to North Side rapid transit stations. The access mode was either bus or walking. The rapid transit destination stations were on the Howard, Ravenswood, or Milwaukee lines.

This existing data was developed in a disaggregate manner, based on the CATS 1970 Home-Interview Survey.[1] The survey provided the census block of the origin and the entering rail rapid transit station for each trip. The access mode and travel time were calculated based on the assumption that the minimum unfactored travel time path to the station was followed.[2]

Travel times were based on two assumptions, a walking speed of three m.p.h. and a waiting time of one-half the headway of the bus. The travel times developed for bus access trips represent the average peak period headway and speed of selected North Side buses (5.4 minutes and 10 m.p.h., respectively).

Data Analysis

A random sample of 50 individual trips was chosen from the base data. The access travel time in both unfactored and equivalent time was available for each of these trips. The access distance in street miles was measured from the centroid of the origin block to the entering rapid transit station. Of these 50 trips, 21 (42%) had walking access and 29 (58%) had bus access.

Unfactored Access Time Model

Figure 1 illustrates the relationship between distance to a rail transit station and unfactored access time to that station. As shown in the figure, only one of the sample walk trips covered a distance longer than a half-mile, and conversely only two of the sample bus trips were shorter than a half-mile. Thus, one-half mile can be considered the indifference distance between walking and bus access.

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[1] Source: Johnson, Permut, Szakos, "A Comparison of Rail Rapid Transit Facilities in the North-Southwest Corridor of Chicago," (MS thesis), Unpublished Files, Illinois Department of Transportation, June 1975.

[2] In certain cases, where the survey data indicated that the minimum time path was not followed, the indicated access mode and path was used.

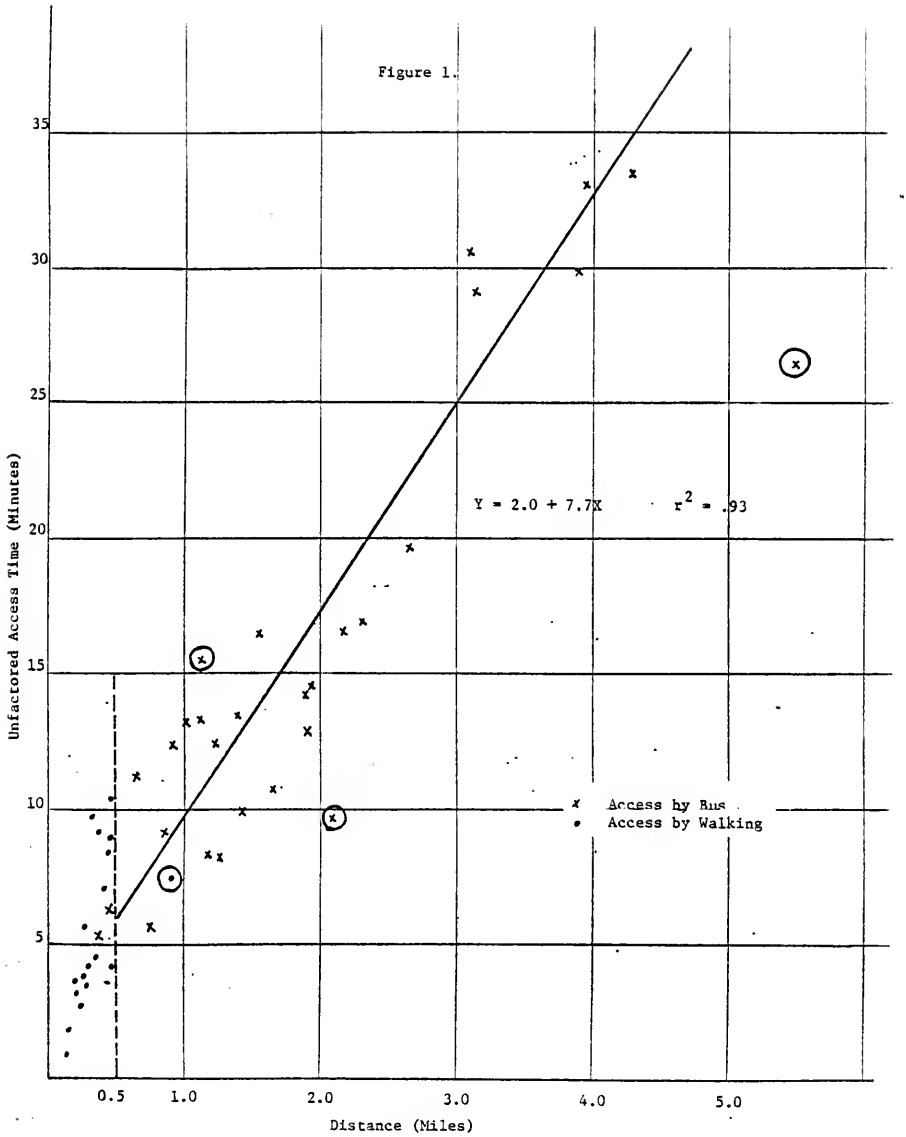
Figure 1.
35
30
25
20
15
10
5
Unfactored Access Time (Minutes)
Y = 2.0 + 7.7X
r² = .93
Access by Bus
Access by Walking
0.5
1.0
2.0
3.0
4.0
5.0
Distance (Miles)

For trips from zones whose centroid is less than a half-mile from a rapid transit station, a walking speed of three m.p.h. could be assumed. However, it can be argued that walking trips are not equally distributed around the zone centroid with respect to access time to the rapid transit station (i.e. they are located in those parts of the zones closest to the station), and, thus the geographic center of these trips is not the zone centroid. If this were so, an adjustment in the distance between the zone centroid and rapid transit station (i.e. decreasing the measured distance) would have to be made prior to the calculation of access time from the zone. This hypothesis is tested in a later section of the paper.

For trips longer than a half-mile, the following bus access regression equation was developed:

$$Y = \underset{(.9)}{2.0} + \underset{(.4)}{7.7}X \qquad r^2 = .93$$

where Y: unfactored bus access time (in minutes) to the rapid transit station

X: street distance (in miles) from the origin block to the rapid transit station.

( ): standard error

This equation does not include the data points which are significantly different (i.e. the circled points in Figure 1).

Equivalent Access Time Model

Figure 2 illustrates the relationship between distance to a rail transit station and equivalent access time to that station. For equivalent time, one-half mile remains, by definition, the indifference distance between walking and bus access. This follows from the method used in the original work to determine the access mode in that for almost all trips the access mode was based on the minimum time path in unfactored time. Therefore, the access mode in equivalent time is the same as the one in unfactored time, and thus, one-half mile is the indifference in equivalent time.

Eliminating those trips which are significantly different, the following regression equation was obtained for bus access trips:

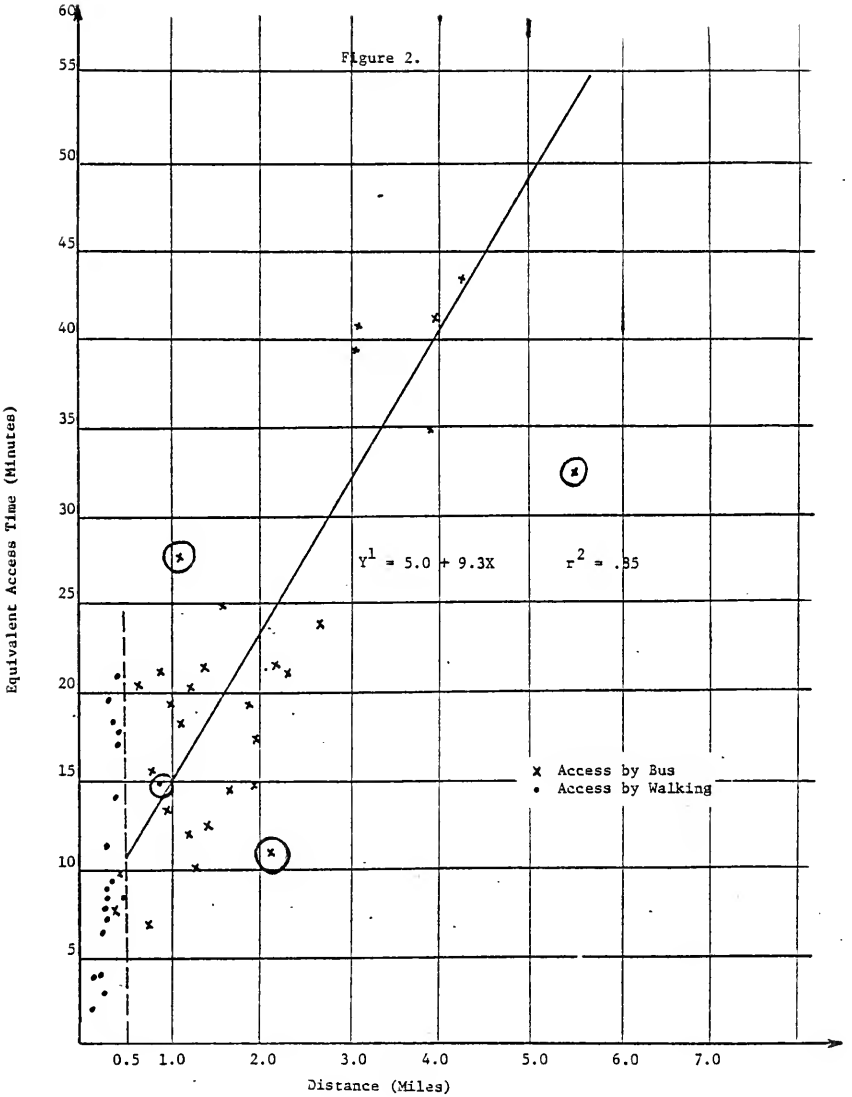
Figure 2.
Equivalent Access Time (Minutes)
60
55
50
45
40
35
30
25
20
15
10
5
0.5
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Distance (Miles)
$Y^1 = 5.0 + 9.3X$
$r^2 = .85$
Access by Bus
Access by Walking

$$Y = \underset{(1.8)}{5.0} + \underset{(.8)}{9.3}X \qquad r^2 = .85$$

where Y: equivalent bus access time (in minutes) to the rapid transit station

X: street distance (in miles) from the origin block to the rapid transit station.

Utilization of Walking and Bus Access Models

Based on the indifference distance of one-half mile, all trips from zones whose centroids are within a half-mile of a rapid transit station have walking as the access mode. Conversely, all trips from zones whose centroids are greater than a half-mile from a rapid transit station have bus as the access mode.

Test of Walking Access Time and Disaggregate Bus Access Models

Aggregate analysis was undertaken to test: (1) the validity of treating the zonal centroid as the center of walking trips from the zone; and (2) the accuracy of the disaggregate bus access models when applied to square mile traffic zones.

The analysis used a data base similar to the one used in calibrating the disaggregate models, except trips using the Douglas and Englewood-Jackson Park lines as well as the Milwaukee, Ravenswood and Howard lines were included.[1] The basic units were CATS zones located at varying distances from rapid transit stations. Map 1 illustrates the zones used for the analyses.

For each CATS zone, the street distance from the zone centroid to the nearest rapid transit station was measured, while the zonal access time was the average of the access times for all individual trips in the zone which enter the specified rapid transit station.

Test of Walking Access Time

As mentioned previously, it can be argued that for zones whose centroid is within a half-mile of a rapid transit station, walking trips are not uniformly distributed around the zonal centroid with respect to distance from the rapid transit station, and that the geographic zonal centroid is not the "true" center of these trips.

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[1] Johnson, Permut, Szakos, ibid.

A regression equation, in unfactored time,[1] which can test whether the zonal centroid represents the center of the walking trips, has been developed for the six zones shown in Map 1. The regression describes the zonal walking time to a rapid transit station (based on the average walking time for all trips in the zone) as a function of the street distance from the zone centroid to the rapid transit station. The equation is:

$$Y = \underset{(1.4)}{-1.55} + \underset{(4.9)}{20.9X} \qquad r^2 = .82$$

where Y: unfactored walking access time (in minutes) to station

X: street distance (in miles) from zone centroid to station.

The above equation can be interpreted to mean that it takes approximately 20 minutes to walk a mile, i.e. the walking speed is 3 m.p.h. Therefore, the zonal centroid does accurately represent the goegraphic center of walking trips from a zone, and can be used as the point from which street distance to a rapid transit station is measured.

Test of Disaggregate Bus Access Models

The purpose of this analysis is to test the accuracy of the disaggregate bus access models when applied in an aggregate manner to mile square traffic zones. This is done by treating the model results as the predicted value for a zone and the average of the individual trip values as the observed value for the same zone. The observed and predicted values are then compared. This was done for the nine zones shown in Map 1.

Various statistical tests comparing the predicted results of the disaggregate models with the actual data were obtained. These results are shown in Table 1.

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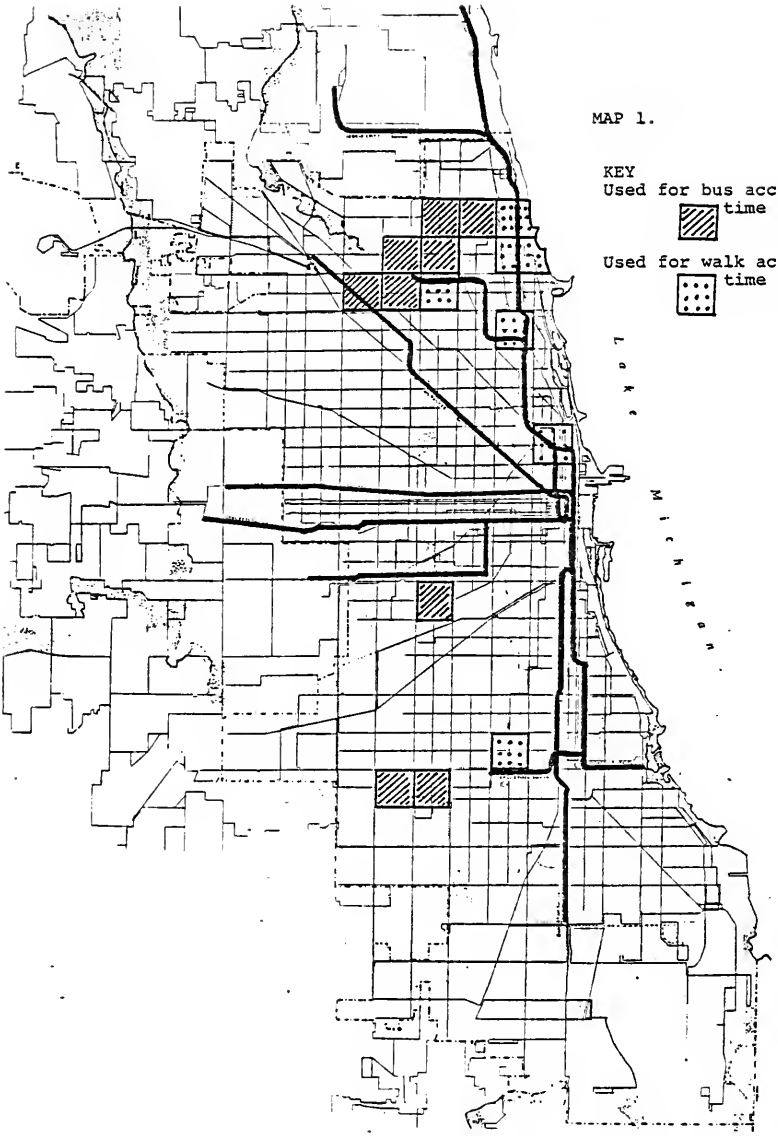
[1] If this model were developed for equivalent travel time, it would have coefficients and standard errors twice as large, but the coefficient of determination (r^2) would remain the same.



MAP 1.

KEY
Used for bus access time test

Used for walk access time test

TABLE 1
Validation Statistics

Model	Correlation Coefficient (r^2)	Root Mean Square Error	Average Percent Error[1]
Unfactored Disaggregate Travel Time	.70	3.7	19.0%
Equivalent Disaggregate Travel Time	.48	5.3	24.0%

These results indicate that the disaggregate unfactored bus access time model provides accurate results when applied on a zonal level, and, thus[2], can be used in an aggregate travel demand analysis process. However, the disaggregate equivalent time model

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[1]The functional form of these two statistics are:

Root Mean Square Error: $\sqrt{\sum_x \frac{(O_x - E_x)^2}{n}}$

Average Percent Error: $\left(\sum_x \frac{/O_x - E_x/}{O_x}\right) x \frac{100}{n}$

where O_x: actual zonal travel time
E_x: predicted zonal travel time
n : number of zones (n=9)

[2]Although there is some error, it should be realized that access time is a relatively small component of total door-to-door travel time. Also, the errors in estimating access time are additive to and not multiplicative with other errors in the travel time estimation process. For these two reasons, errors in estimating access time have a limited effect on the total error in estimated door-to-door travel time. For example, if access time comprises 20 percent of total travel time, an estimation error of 50 percent for access time would only result in a 10 percent estimation error for total travel time.

Note also that part of the unexplained variance is due to the variance of individual trips within the zone, and this variance would exist for any method which treats a simple point as representative of a zone (i.e. this problem would exist even if a coded feeder bus network were used).

does not provide as accurate results when applied on an aggregate level. An analysis was undertaken to determine the reason.

Based on the original disaggregate data, a model which estimates the out-of-vehicle proportion of total equivalent time as a function of distance was developed. The hypothesized relationship was that the greater the distance from a rapid transit station, the smaller was the out-of-vehicle time component (i.e. the greater the amount of bus line-haul time). This was borne out, as is shown in the relationship developed in Figure 3. This fit does not include the significantly different data points.

For each test zone, the estimated total equivalent travel time (by the disaggregate model) was sub-divided into its out-of-vehicle and in-vehicle components based on the model in Figure 3. Then, the correlation coefficients between estimated out-of-vehicle and actual out-of-vehicle time, as well as between estimated in-vehicle time and actual in-vehicle time were determined, and are .24 and .52 respectively.[1]

Thus, the relative inaccuracy of the disaggregate model in estimating equivalent bus access time on a zonal level is due largely to its inability to accurately predict the out-of-vehicle time component. Relatedly, the greater importance of out-of-vehicle time in equivalent time is the reason for the lesser accuracy of the equivalent time model as compared to the unfactored time model.

Conclusions

This analysis has addressed a series of questions concerning the estimation of access times to a rapid transit station. The following conclusions were reached:

(1) one-half mile is the indifference distance discriminating between the walking and bus access mode;

(2) for zones within a half-mile of a rapid transit station, a walking speed of three m.p.h. applied to the street distance between the zone centroid and the rapid transit station provides an accurate estimate of average zonal walking access time to that station;

(3) a regression equation, developed for individual trips, can be used on a zonal level to estimate unfactored zonal bus access time to a rapid transit station as a function of

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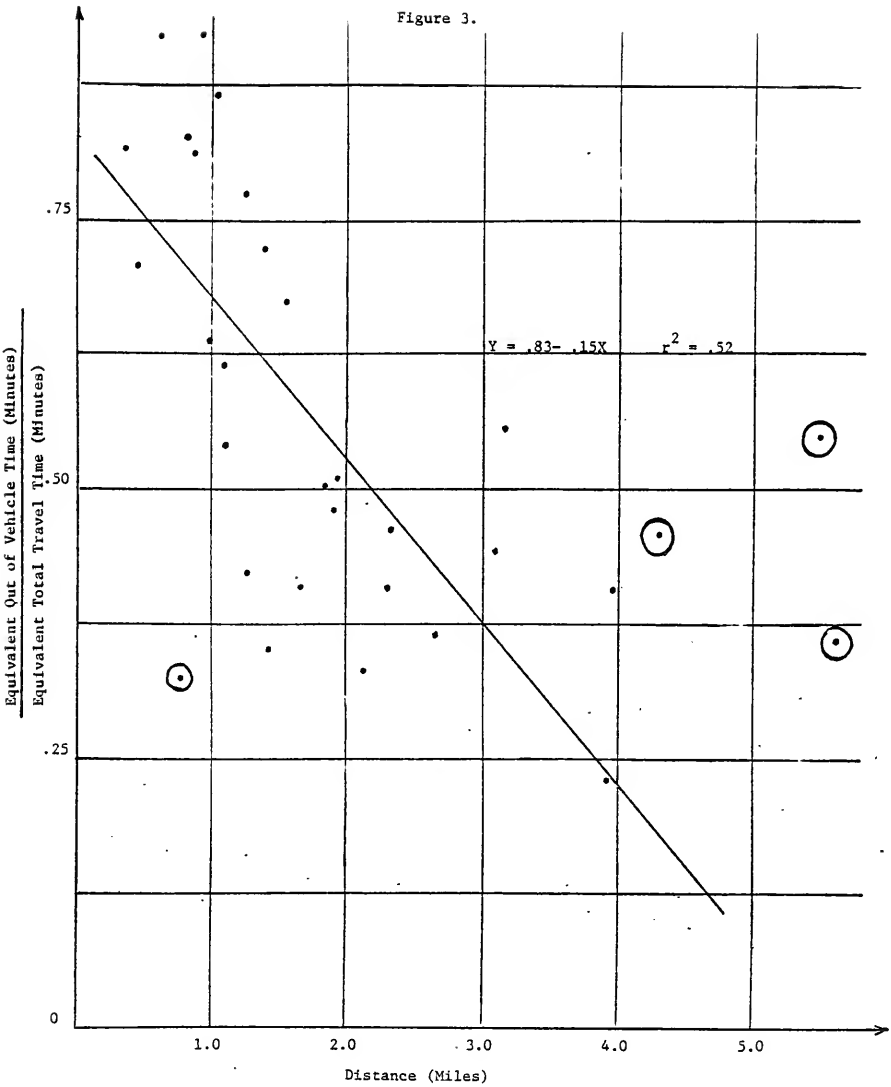
[1] The actual in-vehicle and out-of-vehicle times are the averages of the components of the individual trips.

Figure 3.


Equivalent Out of Vehicle Time (Minutes)
Equivalent Total Travel Time (Minutes)
.75
.50
.25
0
Y = .83- .15X
r^2 = .52
1.0
2.0
3.0
4.0
5.0
Distance (Miles)

distance to that station; and

(4) a similar regression equation, developed for individual trips, which estimates equivalent bus access time to a rapid transit station as a function of distance to that station does not provide as accurate results when applied on a zonal level.

Recommendations for Application

It is felt that the above results have different levels of applicability. The determination of a one-half mile indifference distance between walking and bus access agrees with the results of numerous other studies, and can be generalized to areas other than the City of Chicago. The unfactored and equivalent travel time models are specific to the City of Chicago; but could possibly be used in other areas with a similar level of bus service.

Most important, the above model forms are recommended for use wherever possible since they are area specific, provide accurate results, are very easy to develop, require an extremely small data set, and eliminate the need for a coded feeder bus network.